Dear Paul,

Thank you for your letter. Let me first deal with your criticism of my introductory observables like $Q_1 = Q(1)$ and $Q_2 = 1 \otimes Q$ in my discussion of PII.

Of course it is perfectly true that probing at spacelike separations physical magnitudes [illegible] states. But this does not reinstate MB statistics, when account is taken of restrictions on the accessibility of states. When specifying a weight over a ~~basis~~ set of basis states in quantum statistical mechanics these states must all be mutually accessible under the dynamical interactions involved.

But if: (a) we impose a symmetry restriction on an initial density matrix and (b) assume time-development is effected by a symmetric hamiltonian, then B-E or F-D statistics follows in the usual way.

Let me first comment on (2): How can I know of falsifying it.

(1) The total energy is an observable and all observables are symmetric

(2) The classical hamiltonian for the total system is symmetric, so the quantum hamiltonian, by correspondence argument is also symmetric.

(3) time-development under a specified

dynamic hamiltonian is introduced as an independent dynamical postulate ~~on~~ of our theory.

All these three arguments reinforce one another. Thus, returning to (3) if dynamical evolution were effected by an infinitesimal generator which was not dynamical we would be contradicting the formalism of quantum mechanics

My defense for introducing $\hat{Q}_i$ and $\hat{P}_i$ is based on distinguishing physical magnitudes from a proper subclass of observables

The former need not be dynamical whereas the latter are dynamical. Time evolution of all states of whatever dynamics is governed by the total energy as infinitesimal generator which leads to reduction of state ~~accordingly~~ as described above.

Now with regard to (a). I regard this as logically possible, but as unsatisfactory messing up the contingency usually associated with initial conditions with the necessity of laws.

The field-theoretic approach is much to be preferred.

You are quite right about my overall plan. — Show that the particles approached is logically possible but that the field approach is much more satisfactory on more detailed matters of theory something about the distinction between particle and formulations is needed to explain what is going on.

We expect lecture with detail on the higher statistics (para particles, but I think the question - does QFT apply to para particles is of exceptional interest, and needs explaining.

I like your very clear summaries of the arguments, and it will be very helpful to work from these.

With regard to dates for your visit exams start on the 25th May so the last time for a 3-week visit would be to end around the 15th or 16th of May.

I enclose my referee's report on your Phil Sci paper. I have filled Britt - I do not want to read into behind arguments!

With best wishes

Richard

Hope you can read the writing - I am myself better with dictation than the W-P.

18.4.88

Dept HPS
Free School Lane
Cambridge

Dear Paul,

I have just received your last letters, simultaneously thro' the post and via Hugh.

I defer more complete discussion until you arrive on the 8th May.

But a couple of quick points:

(1) With regard to the travelling and standing waves, you have quite understandably got in a muddle, since my Eq.(9) is misprinted and should read

$$\left[q_R(t), p_{R'}(t)\right] = i\hbar\,\delta_{R,R'},$$ etc.

This follows at once by inverting (6) & (7) and substituting from (1).

You will now find no inconsistency with

(3) and (12).

The transformation to standing waves involves just $q_k + q_{-k} \to Q_k$

where Q_k is real ($Q_{-k} = Re\, q_k$)

Then $q_k e^{ikx} + q_{-k} e^{-ikx} \to Q_k \cos kx$

+ - - -

which signals a standing wave.

Decompose the Q_k into creation and annihilation operators for the real oscillator, and check that H is diagonalized but not P because the eigenvalues of the transformed number operator mix k and $-k$.

Fermi (and also Dirac) discuss the transformation for the photon field but do not calculate the momentum in the way I suggest.

2) [illegible]
field: One must distinguish
a quantum field from a particular
state of a quantum field. The latter
ties probabilities for measurement
of local observables to set parts
The former is essentially a catalogue
of all possible sets of probabilities
associated with all the states -
the situation is just the same
in classical field theories,
distinguishing the concept of 'electric
field' from a particular state of
an electric field.

I hope these brief remarks are
of some use.

Looking forward to seeing you on
the 9th.

With best wishes

Rudolf

RP

PS If you want to spend ~~Hen~~ Sunday night in London, to recuperate from the journey, you can, of course, stay at Ongar Road, and then come on to Cambridge on Monday 9th. Jennifer will be in London that weekend, although I shall probably be in Cambridge.

PPS. I am afraid I have not had time to do any more writing for the book myself. The next chunk may have to wait until we are through with the term!

2151 Hartrey
Evanston, IL 60201
February 17, 1988

Dear Michael,

Enclosed is a more complete outline of a proposed chapter 3. I owe you some comments on what I think goes wrong in the positive arguments in your paper with French. But first, some other thoughts.

Most importantly, I've committed so many thousands of howlers in my life, many of which you have so graciously corrected. I do hope this is not another one. Or rather, if this is one of the times I've got it all wrong, I don't mind at all, just as long as you don't get annoyed with me for having to straighten me out. I'm eager to listen to what you have to say and write. That being said, I'll proceed to lay things out as I now see them.

I am having doubts about whether chapter 3 is worth doing at all. The core argument is both trivial and well known. But perhaps there is something accomplished: the point that what quantum statistics tells against is TI_1, not PII. If this is not generally appreciated, then perhaps the material is worth including. It is also the point which bears on the rest of the book!

Perhaps something more should be said about PII presupposing TI_1. I'm going to pick the brains of some of my historically minded colleagues.

I'm very uneasy how you are going to react to my having taken out ALL, the calculations, ALL the group theory, ALL the material on paraparticles. It is all extremely interesting. But, as things stand, I'm not seeing how that material advances our argument. To be happy to include these things I need to be convinced that points made in this, or later chapters really need them.

Now to address your positive arguments. I am working from the manuscript which I think you gave me last spring.

You point out that IF (a)the real states are all & only (8) and (superpositions of) (5), (6), and (7); and IF (b)the Hamiltonian is symmetric, then the available possibilities are cut down. But, I claim both (a) and (b) are problematic.

The form of argument is: Assume TI_1, then show that one can account for the quantum statistics, thereby showing the consistencey of quantum statistics and TI_1. But, given the assumpiton of TI_1, (a) is false. This is argued in the last letter and in the outline.

Turning to (b): The argument why the Hamiltoneain is symmetric is that, given the indistinguishability postulate, ALL observables are symmetric. (Did I get your justification right? Your footnote 6 says that the reason will be come clear in section 3, but you leave it to the reader to fill in.) However, when TI_1 is assumed, we get genuine property representing self adjoint operators ("observables") which are NOT symmetric. I argue this in the outline, and you also assume it by assuming that your O_1 and O_2 are such observables. Thus, assuming TI_1 is inconsistent with the indistinguishability postulate, undermining your justification for the symmetry of the Hamiltonian

Finally, turning to the arugment of section 4, I guess it does show that if there were properties corresponding to O_1 and O_2, then the individuatable entities assumed would violate PII. But the argument in the outline shows (I think!) that the antecedent of this counterfactual is at odds with the facts of quantum statistics, and so false. So the conclusion does not seem very interesting to me. You took yourself to have shown that TI_1 is consistent with quantum statistics, in which can the conclusion would be much more interesting. But I'm disagreeing with the prior conclusion.

There is, actually one aspect of all of this which is distressing me. I got a letter from French telling me that he has visa and contract problems and probably will have to leave Brasil right away. If my arguments should be right, I do hope it does not have the consequence of resulting in your paper being withdrawn. Hopefully, it's already gone to press. If not, on the assumption that my worries are well founded, I certainly don't feel the need to see the paper withdrawn. It expresses an argument which is most worth sorting out and raises the reader's consciousness about this material. For example, I feel I have learned a great deal by sorting through it.

So that's it for now. I'm going to give chapter 3 a rest - let it percolate, and wait to see what you say. I'm off to do an external review of the Minneapolis department, which will cut next week in half. But when I return I'll go to work digesting chapter 4.

Best to Jennifer. And in additions to giving me your reactions to this material, do let me know what will be good for you for dates for my visits in May, as I asked in my last letter.

Yours,

Paul

P.S. Again, I am very apologetic that I did not come up with these questions way back in 1982! Now that it occurred to me until I started to read the Hartle & Taylor article, and I to see the importance of the principle of Genuine States

Is there a better name for this?

VII. The principle of genuine states:
  A. We suppose a Hilbert Space is given (here $H_1 \times H_2$). H_1
  B. We suppose a set $\{O_i\}$ of operators
    1. From among the self adjoint operators
    2. The subset which count as physical properties
    3. To be called the (genuine) "observables"
    4. $|r\rangle \sim |s\rangle$ iff $\langle r|O_i|r\rangle = \langle s|O_i|s\rangle$, all O_i
    5. Justification
      ->
        (1) If $|r\rangle$ and $|s\rangle$ are the same state
        (2) They should not differ as to properties
        (3) Or potential for properties
      a) <-
        (1) We won't need this
        (2) It is more contentious
        (3) Turns on saying that all genuine facts must turn up in some expectation value.

VIII. Argument that Qm particles cannot have TI_1
  A. First formulation of the argument:
    1. If there is TI_1, O_1 and O_2 are distinct observales.
    2. Let subscripts on states indicate the particle lables
    3. $\langle s_2 r_1|O_1|r_1 s_2\rangle = r \neq s = \langle s_1 r_2|O_1|r_2 s_1\rangle$
    4. So $|r_1 s_2\rangle$ and $|r_2 s_1\rangle$ represent different states
    5. But then we should get classical, not quantum statistics
  B. Second formulation of the argument:
    1. Empirically we observe only statistical behavior represented by symmetric and antisymmetric states
    2. If quatum systems had TI_1 $|r_1 s_2\rangle$ would be a real state.
    3. But it is not symmetric or antisymmetric

IX. Implications
  A. Comparisons with other presentations of this familar argument
    1. Our formulation
      a) Assume TI_1
      b) Arive at conclusions at odds with the facts
    2. Bearing on PII
      a) We formulate PII as presupposing TI_1
      b) TI_1 is false
      c) So PII is inapplicable rather than false
      d) The rope analogy
        (1) Quantum statistics undermines PII no more than the rope analogy
        (2) Rather they both show that TI_1 does not apply.
  B. Relevant conequence for our work: TI_1 does not apply.

2151 Hartrey
Evanston, IL 60201
February 15, 1988

Dear Michael,

I hope you have received the letter I sent three days ago about chapter 3.

This is a quick note on a practical matter. Microssoft has come out with an updated version of Word, MS Sord 4.0. The review say that this version is enormously imporved, and you can order it for $75 as an update if you have the older version. I have my copy on order, and if you want I could send you duplicates of my disks. However, the new package is supposed to come with complete nes documentation, and since there are a lot of changes, that is problably worth having. If the department can put up $75 for this it probably would be a good investment.

I've enclosed the brchures and order forms.

Coming under separate cover.

Yours,

Paul

while I'm on leave
I get things more quickly

here → 2151 Hartrey Ave
Evanston, IL 60201
February 15, 1988

Dear Michael,

I've finally gotten to work on the book. I've read through all the material you sent and have started thinking about chapter 3. This is largely based on your paper with French, and I've now done what, in principle, I should have done when you first sent me the paper, namely to take three days to think it over very carfully, including absorbing section II of the Hartle and Taylor article. I feel very badly that I did not do that before, because I find I'm in dsagreement about the basic point, which I did not appreciate before because I did not connect it with some of the things I've learned in the Hartle and Taylor article.

As I understand your argument, it goes like this: Suppose that particles CAN be individuated, so that O_1 and O_2 represent genuine, dinstinct properties. Then applying these properties to admissible states we see that the indivduatable particles have all the same monadic and relational properties.

Here is my problem: If you augment the set of "genuine" physical properties ("observables"), there is a correlative increase in what counts as distinct states. This follows from the principle that two vectors correspond to the same state iff they yield the same expectation values for all GENUINE properties (observables). If O_1 and O_2 are genuine properties, then $|r_1 s_2\rangle$ and $|r_2 s_1\rangle$ are genuine DISTINCT states, because they yield distinct expectation values ($r \neq s$). But then we should expect to see classical, not quantum statistics. I conclude that O_1 and O_2 cannot afteral be genuine properties.

I've sketched the presentation of this argument in the enclosed outline. At point II.C.1. I want to put in some stuff about what properties should count as genuine properties according to the theory: It's not observability in any strict sense. Rather what counts is capacity to make some impact, direct or indirect, on observation. The claim will then be that this needs to show up in expectation values, even though these expectation values themselves might be hightly "theoretical", that is detectable only on the strength of a great deal of inference. Detection of expectation values in particle physics are generally like this.

Whether or not I am right about all of this, it seems to me that we need to go over these considerations. If I am wrong, your present conclusion will stand out more clearly.

Let me say something about a larger perspective on the manuscript you sent me. It seems to me that, in part, it follows the following plan. We might interpret QFTh in terms of particles or in terms of field excitations. Let's follow out

both alternatives and see how well each one stands up. Your present version of chapter 3 explors the particle approach and concludes that the consequences seem quite strange. Chapter 4 - second quantization - lays the ground work for carying out transition to QFTh while preserving as much of the particle picture as possible. In chapter 6 we will see that we get the same formalism from a field theoretic point of view, and given the qualms generated in chapter 3 there will be a case for preferring the field theoretic view point. Or we could leave it to the reader: If you feel you can swallow the strange ways in which these are still particles, go ahead.

Two comments: Have I in fact discerned the program in the back of your mind? If such a format is what you have in mind, or if you are in any case quite happy with it, then it needs to be brought out more clearly.

Second: On this view of the larger structure of the book, my disagreement with you about chapter 3 won't make a big difference to the larger program. We need to reach agreement on just how bad the chapter 3 considerations are. When we do, it should fit in very well either way.

A question about procedure: How well can you follow what I'm saying with an outline like the enclosed? I'm hoping you will get my drift quite clearly enough. If so, you will save a lot of time reading, and changes can be made much more quickly. Do let me know how well this sample works for you.

Another comment on chapter 3. You have a lot of tehcnical material on the permutation group and its applciation. As things stand I don't see how it is doing any real work for us. In a week or so I'll try to send you a longer outline, constituting a proposal for how to do the chapter with a good deal less technical material. Do let me know what you think.

I should make my plans to come to visit! Earman will be speaking on May 24 and 25, as I understand it. When do your duties working on exams descend on you? Please let me know how long you will be relative free to talk about the book. My schedule is quite flexible. I'll plan to come for around 3 weeks, for example May 10 through May 31. Do let me know what will be convenient.

Hope to hear from you soon!

Yours,

Paul

Outline for chapter 3, February 15, 1988

I. Surplus formal structure
    A. Start with a one particle hibert space, H.
    B. Form the n-particle product space, $H_1 x H_2 ... H_n$.
    C. Vectors in this recognize distinct permuted particle states.
    D. Need to
        1. Determine which structure is surplus
        2. Eliminate the suprlus formal structure

II. The principle of genuine states:
    A. We suppose a Hilbert Space is given (here $H_1 x H_2 ... H_n$).
    B. We suppose a set $\{O_i\}$ of operators
        1. From among the self adjoint operators
        2. The subset which count as physical properties
        3. To be called the (genuine) "observables"
        4. Justification
    C. $|r\rangle \sim |s\rangle$ iff $\langle r|O|r\rangle = \langle s|O|s\rangle$, all O_i
        1. Justification

III. The principle of genuine states eliminates surplus formal structure.
    A. Well known example: Only rays characterize states
    B. Similarly, for smaller $\{O_i\}$ group theory gives
        1. vectors, or
        2. rays,
        3. or invariant subspaces (paraparticles)

IV. Argument that TI, or a property which turns on TI, cannot be a genuine property in QM
    A. Let r, s be distinct eignvalues of an operator, O, in H.
    B. Let $O_1 = O x I$ and $O_2 = I x O$.
    C. Suppose that O_1 and O_2 are genuine observables (properties).
    D. Let subscripts on states index particle place.
    E. $\langle s_2 r_1|O_1|r_1 s_2\rangle = r \neq s = \langle s_1 r_2|O_1|r_2 s_1\rangle$
    F. So $|r_1 s_2\rangle$ and $|r_2 s_1\rangle$ represent different states
    G. Which is to say that particle order DOES make a difference.
    H. But then we should get classical, not quantum statistics

Outline for Chapter 3 February 17, 1988

I. Our interest in PII.
    A. Debate as to whether quantum statistics disproves PII
    B. We believe: PII is inapplicable, rather than false
    C. Because the ontology of quantum theories do not have the individuatable things to which PII applies
    D. It is this conclusion about ontology of QThs which interests us.

II. An analogy
    A. Two paradigms for a Quantum ontology
        1. Classical particles
        2. Classical wave processes
    B. On the latter alternative, a quantum "object" is like a bump on a shaken rope
    C. PII inapplicable to such "rope bumps"
        1. Two bumps traveling in from the rope's ends
        2. Meet in the middle
        3. Does this provide a counter e.g. to PII?
            a) Would need to say that there are TWO things
            b) With all the same properties
            c) But seems wrong to say there are two things in the merged bump.
    D. We will argue that attempts to disprove PII from Q Statistics are like this parody

III. Terminology and basic ideas
    A. Items: universals and particulars
    B. Particulars
        1. Events and states (occur or obtain in s-t)
        2. (Physical) individuals (exist in s-t)
            a) Individuatable
                (1) Can be counted
                (2) Rearranged: If the attributes are switched, we have a different situation
            b) Continuents
    C. Two questions about individuals
        1. In virtue of what can they have attributes?
        2. In virtue of what can they be individuated?
        3. Traditionally one postulates some one aspect to answer both questions.
            a) Lockean substratum
            b) Aristotelian prime matter (?)
            c) Transcendental Individuality
    D. These two questions can, and should, be separated
        1. TI_1: That in virtue of which physical objectes are individuated
        2. TI_2: That to which attributes attach
        3. The recent "hole argument" indicates that s-t points, at least, have TI_2 but not TI_1.

IV. PII
  A. Identity
    1. Suppose that individuals have TI_1
    2. Suppose that names or lables, 'a', 'b',... attach directly to individuals in virtue of their TI_1.
    3. So that a=b iff 'a' and 'b' are attached to the very same TI_1.
    4. (Note that in this way we avoid obscrue appeal to "identity" as a "relation").
  B. PII
    1. Suppose TI_1 does not count as an attribute
    2. (F)[Fa <-> Fb] -> a=b
    3. A substative thesis
  C. Strong and Weak PII
    1. Weak: (F) includes properties of spatial location
    2. Strong: (F) excludes properties of spatial location
    3. Leibniz apparently subscribed to Strong PII

V. PII in classical physics and pre-scientific ontology
  A. S-t trajectories as a mark of TI_1
    1. Suppose that attribute bundles have continuous s-t trajectories
    2. Suppose the Inpenetrability Assumption (IA)
    3. Suppose that s-t trajectories go with TI_1.
    4. Then Weak PII holds
  B. So s-t trajectories (+IA) can do the work of TI_1
    1. Insofar as we are not worrying about TI_2
    2. We can foget about TI_1 and let the s-t trajectories serve to individuate.
  C. This trivializes Weak PII, but accounts for M-B statistics
    1. To get weak PII we let (F) range over the s-t trajectories (the ersatz TI_1)
    2. Making PII trivially true
    3. But now we get basis for MB statistics
      a) (Read 'C_{H1}' as 'Coin$_1$-heads' etc.)
      b) C_1H & C_2T is distinct from
      c) C_1T & C_2H
      d) Because C_1 and C_2 have distinct, individuating s-t trajectories
  D. QM can't use s-t trajectories as ersatz TI_1
    1. No well defined trajectories
    2. Superposition, so no IA

C_1H

VI. Statement of the problem in QM
    A. Intrinsic and contingent properties.
        1. Intrinsic properties
            a) Quantum systems have mass, charge
            b) On which all particles of the same kind agree
            c) Irrespective of the state of the system
        2. Continent properties
            a) Given a system of a given kind
            b) Different quantum states attribute different values of position, momentum, spin, etc
        3. Particles of the same type, with the same intrinsic properties are called Indistinguishable.
    B. Does a quantum system with more than one "unit" of indistinguishable quantum substems have individuatable members?
        1. We will show the consequences of saying "yes"
        2. In preparation we show how to describe this circumstance.
            a) We consider systems of a fixed kind
            b) One such system rerpresented in H
                (1) Has states represented by rays in H
                (2) Observables represented by self adjoint operators, O, on H
            c) Suppose that such systems are individuatable
                (1) Have TI_1
                (2) And so can be labled.
            d) Then two particle states can be represented in $H_1 x H_2$
                (1) Let O be an observalbe on H with disintct eigenvalues r and s
                (2) Let $O_1 = OxI$ and $O_2 = IxO$
            e) O_1 and O_2 represent distinct observables
                (1) "Observable" need not mean actually discriminable
                (2) Rather, they correspond to real (potential) attributes
                (3) Since the two subsystems have TI_1
                (4) There is a difference in fact between
                    (a) 1 having value r and 2 value s
                    (b) And the other way around.
    C. Is this consistent with the facts?